ART. V.—*Animal Chemistry, and its Relations to Therapeutics.*

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AMONG the many problems presented to the consideration of the physician, perhaps none demand so much of his attention as those relating to *Nutrition*, while none are more intricate or more difficult of solution. From the first introduction of the food to its deposition as tissue, or rejection as waste, a series of changes are continuously in progress full of the deepest interest, and on the correct performance of which the comfort, and even the very existence of the individual depend. The growth of infancy to childhood, and of this to mature years, with the future development of a healthy or diseased offspring, the very foundations of individual prosperity and of national greatness, have the due performance of these series of functions for their support and basis; while the daily health of every individual is, in by far the larger number of persons, good or bad, as these acts are well or ill-performed. The prevention of disease, also, relies chiefly on these acts as its sheet anchor, and in their treatment they present an importance of the first magnitude. If they be, therefore, so closely interwoven with every thread of our existence, of how much importance is it that the most correct views be entertained with regard to them, and that we should be able to follow them through their numerous ramifications. In continuing, therefore, our subject of "animal chemistry and its relations to therapeutics" we shall commence with *Nutrition*.

In its most extended sense this embraces—1. Food and drink. 2. The formation of the nutritive fluid, including the complete digestive act. 3. The nutritive act, properly so called. 4. The removal of effete matter thereby occasioned.

A very extensive work on the subject of food has been lately published at Giessen, by Dr. Jac. Moleschott, of Zurich. The first part, or the text, contains 570 pages; the second consists of 355 tables, covering 254 pages. The tables are chiefly analytical, some being comparative of various articles of food, showing their composition and relative value in several constituents. Such a compilation, if correct, cannot fail of being valuable, condensing a fund of information, which it would require years to collect.

The body of the work is divided into ten parts—1. Elementary Principles. 2. Their course in the Human Body. 3. The Necessity of Food. 4. The Kind and Quality of Elementary Principles required to meet the wants of the System. 5. Animal Meats. 6. Vegetable Meats. 7. Spices, Condiments, &c. 8. Drinks. 9. Physiological Properties of Meats, Spices, and Drinks. 10. On the Choice of Food.

This work may be rather considered as an elementary treatise; after a very careful perusal of the first six and ninth chapters, and a more cursory one of the last, there appeared nothing particularly worthy of notice, except that the author had apparently examined all the travels in all parts of the world with the view of ascertaining on what the inhabitants of different countries subsisted. The analytical department of the subject is entirely omitted. The general chemistry and the physiology are sadly defective; it may be said to be of the most superficial character. Had the author entered into the details of the most reliable methods used in determining the presence and the amount of the various proximate alimentary principles in the different articles of food, and the examinations of these in the various stages of assimilation, and so forth, omitted much of his superficial matter, and thus given the space devoted to the food of savages to the minute examination of the diet of civilized nations, his work would have had a real and important value; as it is, the tables in the end are the only parts of much value. The work, however, will answer as a primary introduction to the study of dietetics; or, as a species of light reading, some amusement may be derived from learning the dietetics of distant lands. In his physiology the author follows the school of Mülder, whose protein and protein oxide theory he altogether accepts.

There is a great natural division of animals into carnivora and herbivora, a subdivision of the latter being graminivora; besides which are omnivora, including man. We have, therefore, in "comparative nutrition," that of all these classes of animals, all and each of which contains a rich field for investigation. Bischoff and Voit have paid particular attention to the nutrition in carnivora, and have lately published a most interesting treatise on it, to which we shall hereafter refer at some length.

The food of man may be briefly enumerated as containing muscular, adipose, and gelatinous tissues, the cereal grains, and various vegetables, milk, salines, and water. The composition of the cereals is very similar to that of muscular tissue, while vegetable albumen, fibrin, and casein, correspond to those of the animal kingdom; only the inhabitants of the Arctic regions and of the Pàmpas of South America adopt a diet exclusively animal, the former using immense quantities of animal fat to supply the want of hydrogen and carbon, while the latter almost live on horseback, constantly using immense exertion, and only continue this mode of living for certain periods. The vegetable kingdom, however, furnishes the largest amount of human food; although flesh meat of one or other kind may be said to be the most important, no dietary being fully adequate to support human life without it, or its analogue equally derived from the animal kingdom.

The parts to be nourished, that is, the tissues, require special consideration, both with regard to their composition and their morphological arrangement. The tissues which have been the most fully investigated are, perhaps, bone, cartilage, and muscle. Other tissues have received a large share of attention, but these will suffice as giving a good general idea of the subject.

The muscular tissue is composed of the muscular fibre or tissue proper, of connective tissue which binds the fibrils into fibres and connects those of each muscle into a unit, of vascular and nervous continuations, and at either extremity it terminates in tendinous expansions connecting it to the parts intended to be moved by it.

The ultimate structure of the muscular fibril is still an undecided question; but, whatever may be the shape of the ultimate element, all authors are agreed that it consists of a cell, and that the fibril is formed by the superposition of these cells in the longitudinal direction. Now, "if in the living animal a muscle be separated from the surrounding tissues and left in connection with the rest of the body, only by the vascular and nervous trunks distributed to it, and then by electrical irritation be excited to repeated and long-continued contractions, there will ooze from its upper surface a yellowish glutinous fluid which will drop so constantly that it may be collected in considerable quantity in a vessel placed to receive it." (Wundt, quoted in *Arch. für Phys. Heilk.*, 1859, p. 146.) This fluid is supposed to be contained in the "plasmatic vascular system" of J. G. Sessing, which, as offshoots from the capillaries, convey only liquor sanguinis as their ordinary contents. Whether as Bowman describes, the muscular cells be discoid, or quadrilateral as according to Queckett, these vessels must pass in the connective tissue between the fibrils; and by their means every single cell throughout the entire muscle may be, and doubtless is, brought into immediate contact with the "living stream," from which it thus derives its nutriment direct, and not by transmission through other cells, as would be the case if the capillaries alone were the smallest nutrient vessels.

The osseous has as intimate relations to the blood stream as the musuclar tissue, for it "is certain that the organization of bone is such that, notwithstanding the rigidity of their structure, they are in the most general and the most intimate relation with the nutritive plasma of the blood. In every situation when the osseous tissue is in connection with vessels, as on the external surface, in the walls of the medullary cavities and cancelli, and those of the Haversian canals, millions of closely crowded minute openings exist. These convey the blood plasma by means of the canaliculi into the lacunæ lying nearest to the surfaces mentioned, from which it is then conducted by wider canaliculi to the more distant lacunæ as far as the outermost layers of the Haversian lamellæ, and those lacunæ of the great lamellar system, which are most remote from the vessels. When the enormous number of the canaliculi and their multifarious anastomoses are considered, it must be allowed that no tissue in the human body is better provided for in respect of the distribution of the blood plasma, whilst in scarcely any other is the direct conveyance of the fluid to the most minute particles more immediately necessary than in it. There can be no doubt that the fluids which this plasmatic vascular system (of Lessing) of the bones obtains from the bloodvessels are most indispensably requisite for the maintenance of the bone." (Kölliker, *Micros. Anat.*, Tr. by Busk & Huxley, p. 338, Am. ed.)

The same *mode* of structure is then found in both these tissues, and the same *method* of nutrition, viz., of direct and immediate contact between the parts to be nourished and the nutritive fluid

By digesting bone in very dilute nitric or hydrochloric acid we obtain the cartilaginous portion of the bone separately by itself, retaining all the shape of the bone, while by calcination the earthy part of the bone is preserved alone, equally preserving the original form. It is certain, therefore, that the two elementary constituents must be most intimately combined, perhaps not in chemical combination, but certainly not in merely mechanical mixture. The exceeding vascularity of osseous tissue shows us that both these elements, the collagenous and the earthy, require and receive a most minute juxtaposition with the nutritive fluid, while the energetic molecular change, which is continually occurring in them, teaches us that after osseous deposits have taken place they are not considered as outgrowths, to be provided for by the chances of circumstances, but that as it was necessary that the primary deposit of the earthy in the collagenous tissue should take place from the plasma, not by an act of crystallization, but by an act of vitality; not by a precipitation of effete matter, but by an act of secretion; and as this plasma must of necessity be brought to the secreting structure by a vascular channel, so this "molecular change" teaches us that these channels of vascular supply are as equally needed for the purposes of nutrition as primarily for those of formation. The diseased conditions of bone point also to the same end, of which the increased density and removal of collagenous element in old age, the defective secretion of the earthy element in rickets, the fatty degeneration in osteo-malacia, may be cited as examples.

To obtain a complete conception of the nutritive fluid it is necessary to examine not only the processes through which every article of diet has to pass, before it or any part of it becomes converted into blood, but also to consider the modifications produced by every separate article of diet as well as by the variations in which these are found in different dietaries. Such a detail being at present a simple impossibility, we shall notice only some of the more prominent features of the subject, and we propose to trace the processes to which the food is subjected in order that from it the nutritive fluid may receive its replenishment; and we shall consider each process separately with its peculiar effects on each element of food, premising that our object is to bring out leading principles, reserving an argumentative consideration of certain points for a future opportunity.

The first process is that of mastication, which needs only to be mentioned as a mechanical act of subdivision, but is of too much importance to be omitted, although too frequently neglected in practice, becoming thereby a "fons et origo mali;" a certain amount of atmospheric air, therefore of oxygen, becomes thereby mixed with the food. The next is the process of insalivation, or the commixture of the food with the mixed saliva. In the *Leçons de Physiologie*, of M. Bernard, vol. ii., 1856, is a full detail of the salivary secretion to which we would refer the reader, giving here only a condensed view of the most important points.

The saliva secreted by the different glands differs widely in its characters and quantity; that of the parotid is the most watery and abundant, and is secreted principally during the act of mastication; that of the submaxillary is more scanty, but more viscous, and is more plentifully secreted during excitation of the nerves of taste; that of the sublingual and buccal glands being the most scanty, but excessively glutinous, facilitating the act of deglutition; the viscous element is called ptyalin. The reaction of the saliva is very alkaline. The secretion is not constantly the same in quantity, but is intermittent, depending on the presence or absence of its exciting causes. It is increased by dry and pungent foods, lessened in amount by moist and sapid food.

On albuminoid and fatty matters the saliva exerts no influence; but it has been long since observed that it possesses the property of converting starch into sugar; this has been attributed to a certain special substance contained in it, which has received the name of salivary diastase; this body is not, however, peculiar to saliva, but seems to be a resultant of the spontaneous decomposition of all nitrogenous matters, whether vegetable or animal, under the influence of oxygen; and it may originate in the saliva from the decomposition of some of the salivary constituents, such as epithelial cells, &c., in the oral cavity itself—a circumstance which is rendered more probable by the fact that morbid saliva is more energetic than healthy, as in mercurial salivation, and in inflammation of the mouth; and the greater activity of human saliva over that of all other animals may be owing to the continual access of air to the oral cavity.

It must be remembered, however, that complete putrefaction destroys this property. The presence of acids also arrests decomposition and prevents the further action of the saliva on the starch, not, however, hindering the operation of such "diastase" as may be already formed if used immediately; but if kept a day or two acidulated saliva no longer acts upon starch. The sole action of insalivation then on alimentary matters is to convert starch into dextrine and glucose or grape sugar. As soon as the alimentary bolus enters the stomach it becomes mixed with the gastric juice, a fluid strongly acid from the presence of lactic, or according to some of hydrochloric acid, and containing the animal principle, pepsine. The quantity of gastric juice secreted is very differently stated by different authors; although a very important matter, we can hardly deduce bases for therapeutic action from our present knowledge; we may say, however, that a certain degree of dilution is necessary for the due performance of the digestive act, and we sometimes find advantage from tepid diluents shortly after eating, in some cases of difficult digestion.

On fatty matters the gastric juice exerts no influence; the fat is simply liquefied and floats free in the mixture known as chyme.

On starch and sugar the gastric juice exerts no influence, but the action of the saliva on the starch becomes hindered as soon as the saliva becomes acidulated by the gastric juice to the extent above mentioned. On albuminous and gelatinous substances the gastric juice exerts a powerful influence, dissolving them, and also modifying their properties, so that they, although previously intransmissible through an animal membrane, now permeate it readily; they become more easily soluble, are less easily coagulable, gelatin ceases to gelatinize, and they lose the property of forming insoluble combinations with most metallic salts; but they are so precipitated by tannic acid, chloride of mercury, and acetate of lead when mixed with ammonia.

In the stomach a large portion of the received matter is absorbed, especially of the fluids. Water is rapidly taken up, as also those solutions which will permeate a membrane having the blood serum on the opposite side, such as spirituous, weak saline, saccharine, and albuminous solutions; it is, however, only a limited quantity of the solid portion of the food that is absorbed in this organ; by far the larger quantity becomes mixed up into that homogeneous mass, the chyme, which is gradually transferred to the duodenum, to be still further modified by the pancreatic, biliary, and intestinal fluids. In addition to the gastric juice the stomach, like all other mucous surfaces, secretes ordinary mucus; that this is not an indifferent substance to the digestive process is seen from the fact that if in large quantities, it acts very injuriously, preventing the operation of the gastric juice, perhaps also to a certain extent supplanting it, and causing fermentations of various kinds, with the formation of abnormal products; in whatever quantity it may be present it, with the saliva, nasal and pharyngeal mucus, and the gastric juice, contain more or less excrementitial matter, which is probably the reason of its becoming an exciter of fermentation, as was observed in the case of the saliva.

A certain amount of atmospheric air, and therefore of oxygen, is conveyed into the stomach, and occasionally of carbonic acid also. Gases are as readily absorbed by the gastric as by any other mucous membrane, the walls of the vessels being as equally exposed; under the influence of heat and moisture, and during the various molecular alterations which here occur, the effects of oxygen are more energetically manifested, especially where the nerve force of the organ is diminished; a point worthy of attention in cases of dyspepsia, attended with production of excessive acidity. The small excess of the nitrogen in expired air over that of the inspired air may be derived from this source; there being no evidence that atmospheric nitrogen ever enters into any combination whatever in the human body.

The especial action of the pancreatic juice, which is a highly albuminous, alkaline secretion, is to convert starch into sugar, and to emulsify fats, so that they are easily absorbed. Bernard (op. cit.) gives a very full account of the pancreatic secretion, and its influence in digestion; according to him, it serves also to redissolve albuminous matters, after they have been precipitated by the bile, from their state of solution in the gastric juice. The chief exception to his account of the digestion of fat by the pancreatic juice is its formation into glycerine and fatty acids; such an acidification of oil or fat as takes place outside the body would be quite abnormal within the body; it requires a longer period for its accomplishment in a water-bath than could be allotted to it in the intestinal tube; while such a formation of acid as we shall have occasion to notice more at length presently is a general accompaniment of difficulties in the digestive process. The great probability is, that fat is absorbed as neutral fat, emulsified by means of the pancreatic secretion, or chiefly so, that is, divided into small particles, each of which is surrounded by an albuminous envelop.

Poured into the duodenum at the same time with the pancreatic juice is the bile, another alkaline secretion, and one of the most important of all the fluids engaged in the digestive process. The action of the bile, like that of all the other fluids of the digestive canal, is still a subject of considerable discussion; it may assist somewhat in emulsifying fat; it, in all probability, has decided antiseptic properties; it may precipitate albuminous matters from their state of solution. Its water serves largely as a means of transit of biliary matters from the blood, and of nutriment and of other soluble matters from the intestinal tube back again in the blood-stream.

The various glands in the duodenum, jejunum, ilium, and cæcum, still further supply a series of fluids for the solution of nutritive matter, its elaboration and absorption, and the venous radicles throughout the whole intestinal tube collecting the absorbed food, pour it by one common trunk into the liver. As, however, cases are on record where the vena porta, instead of traversing the liver, entered at once into the vena cava, without any disturbance to the ordinary functions of life having been sustained, such an occurrence would prove that the food did not require any further assimilation than what it obtained by means of the various intestinal processes, before being perfectly capable of being applied to the purposes of nutrition. In these cases the liver secreted the bile from the blood of the hepatic artery.

As a summary, then, we may state that albuminous matter, whether vegetable or animal, is absorbed as albumen, gelatinous matter as gelatin, these being both modified, as before stated. Starch and saccharine matters are absorbed as grape-sugar and dextrin, and fat principally as neutral fat, a small portion of fatty or other acids being formed.

According to Moleschott, in his work above noticed, the digestion of amylaceous food proceeds thus: The starch is first converted into dextrin, $C_{12}H_{10}O_{10}$; this absorbs 2HO, and becomes grape-sugar, $C_{12}H_{12}O_{12}$. This change may occur throughout the whole length of the intestinal tube, from mouth to rectum. The sugar then loses 2HO, and becomes hydrated lactic acid, $C_{12}H_{10}O_{10}+2HO$, which occurs partly in the stomach, more so in the small intestines, but principally in the cæcum. The hydrated lactic acid then becomes split up into hydrated butyric acid, $C_8H_7O_3+3HO,4H,4CO_2$, which occurs principally in the colon. This metamorphosis of the fat-formers (Fettbildner) into a series of acid formations, like Bernard's formation of fatty acids noticed above, is open to some very serious objections, is quite contrary to deductions from pathological phenomena, and is quite opposed to the teachings of therapeutics; if followed out, it would certainly lead to a very injurious practice; for if this were the mode of their normal digestion, attacks of *indigestion* would be most readily relieved by the use of means that would *promote acidification;* and in cases of weak digestion, these acids, taken directly, would save all the labour of their formation from these substances, thus a large amount of force would be saved, and digestion would be so much the more easy.

In various pathological conditions, especially in states of hyperæmia and irritation of the gastric mucous membrane, large quantities of mucus are thrown off, while in many of these cases the proper secretion of gastric juice is checked; this mucus very readily enters into or induces various decompositions known as fermentations, partly from want of a better name, and partly because these processes may be simulated by fermentative processes outside the body. Instead, under these circumstances, of the alimentary principles being dissolved and absorbed in the condition produced by the normal or healthy secretion of the part, acids of various kinds are produced; thus, albuminoid, saccharine, and fatty matters will give rise to lactic, acetic, butyric, and other acids, while other foreign bodies will necessarily be formed, containing the nitrogen, sulphur, and phosphorus of the albuminoid matter. These will be as largely absorbed as they are formed, and the consequences will be a disturbance of the ordinary alkaline reaction of the blood, lithic acid will be discharged extensively by the kidneys, either alone, but more generally in combination, other acids will be thrown off in the sweat, various fetid matters will pass off from both skin and lungs, and numerous morbid states induced, dependent on this state of acidity, and the relative weakness of this or that organ. The means of cure assist in the explanation of these phenomena. Alkalies, especially potash, which, forming the most soluble salts, is most readily discharged by the kidneys, alkaline earths, which, forming more insoluble compounds, pass off by the bowels, are the most successful remedies by which, with moderate evacuants, we rid the system of the amount already formed; we then check the further development of such acids, in which the real cure consists. This is done in three ways: one, by directly developing nervous force, as by travelling or voyaging, or much exercise in the open air, and preferably where the mind may at the same time be agreeably entertained; a second, by directly supplying the deficient element, as by administering pepsin; and the third, by mineral acids, tonics, and antiseptics, with or without sedatives and counter-irritants, the food being, at the same time, that most easily and extensively digested by the parts of the intestinal tube least affected, so as to allow the weak part to rest as much as possible, that its irritation may subside, and its force be regained by cumulation. The more we can effect by dietetic management and by hygiene, the more permanent will be the cure, and, with proper care, the less liable will the disease be to return; this much, however, being self-evident, that the manner of life, or whatever cause, first inducing the disease, will be the one most likely to cause its return, and hence a frequent cause of failure in the treatment of dyspepsia, patients either will not or cannot give up or alter that mode of life under the influence of which the disturbance first originated.

If such be the teachings of pathology and therapeutics, the hypothesis of acid formations as the regular mode of digestion of starch, sugar, and fat must necessarily fall to the ground. The subject is one of such vast importance in every-day practice, that the author hopes this seeming digression will be pardoned.

Having thus considered the formation of the nutritive fluid as far as the introduction of true alimentary matter into it, the fact remains to be noticed that all animal and some vegetable foods contain those proceeds of retrograde metamorphosis which are peculiar to the tissue; thus, muscular flesh contains creatine and creatinine, and what other residuary products of the nutritive act may be contained in its retained plasma or blood, particularly when the animal has died without previous hemorrhage. Now, as these are found directly in the excretions as well as in the tissue, it would be contrary to all known principles to suppose that these effete elements, introduced in the food, should be first raised to the condition of albumen, and then retrograde to their original composition. No upbuilding in the scale of composition occurs in the animal economy; all alimentary substances introduced into it must be of the highest and most advanced formation of which they are capable. Albumen, for instance, cannot be supplied by any substance or substances of a lower grade, from which it may be subsequently formed in the organism itself; all that we observe is, that nature has furnished us with several modified forms of the same substance, which are all convertible into one form, which may therefore be considered as the standard or typical form, their elementary composition suffering no changes, or but one of molecular arrangement, as we express it. We find in the carbo-hydrates a similarly convertible family, to which are closely allied the fats, and in the metamorphoses which occur in the processes of assimilation and nutrition the direction is the same; thus albuminous matters may give rise to carbo-hydrates and fats, or their derivatives. Carbo-hydrates may also give origin to fats, but fats cannot give origin to carbo-hydrates nor albuminates, nor carbo-hydrates to albuminous formations. Many, therefore, of the solid parts of the food enter the blood stream, only to be rejected by some peculiar excretion. This is an important principle in the treatment of disease, especially when, from any disorder of function, either of excretion or of formation, any of the principles of retrograde metamorphosis are in undue excess in the blood; in such cases all alimentary substances, which, besides being convertible into such principles in the direct line of retrograde metamorphosis, contain any of them as an already existing element, a consequence of that act of nutrition which maintained their own existence while living, should be avoided. Thus, in some diseases—as fevers—we find a great excess of uric acid, in others of urea; from the changes in whichever of the nitrogenous tissues these or either of them may be derived, a flesh diet, especially gelatinous, which increases their amount, even in a state of health, is prejudicial, while a vegetable diet, under which they decrease, is to be preferred. We find also that the products of fermentation which are contained in food, a consequence of vitality, as in the case of sprouted grain, render it unwholesome.

In addition to the water, sugar, albumen, and fat, the blood contains also another important class of nutritive principles, the salines. Some of these are combined with the nitrogenous principles, and this so intimately, that it is almost, if not quite, impossible entirely to separate them; but in the act of nutrition they become separated when the albuminous body suffers decomposition, and obey the general laws of excrementitious matter. Others of them form a portion of nearly every article of food and drink, so that sulphur, phosphorus, iron, lime, and magnesia are but seldom used as dietetic, though often as medicinal substances, common salt being the mineral especially added to our food as a separate ingredient. As all these are being continually received with the ingesta, and removed with the egesta, they are constant ingredients of the nutritive fluid.

The residua of nutrition, in their transit from their place of formation to that of their excretion, form very important component parts of the blood stream, as also all those unassimilable or unnecessary substances which may have been absorbed during the process of digestion, but are again eliminated by the excreting organs. Among these may be named carbonic acid, urea, uric, phosphoric, sulphuric, hippuric, lactic, and oxalic acids, creatine, creatinine, biliary colouring matter, extractive, &c.

In addition to the above-mentioned components of the blood stream, all of which are present in the fluid or dissolved condition, there are another series of bodies, which belong properly to the class of solid formations, viz., the blood-cells, red and colourless, or the mature and young; these derive their nourishment from the plasma, and give off the residua of their nutrition, and the results of their destruction, to be separated by the eliminating organs; the same rule holding good to them as to all other parts of the system, viz., that those molecules which, under any form, have been used in the processes of life, are no longer capable, when they have once passed through their stage of vitality, of again entering into the formation of animal principles of the same or of a higher order, but are either immediately eliminated, or become so after passing through successive stages of downward or retrograde metamorphosis; thus, the iron of those corpuscles which become destroyed or broken up is expelled, and does not enter into the formation of fresh corpuscles, and its place must be supplied from without, by fresh iron, *i. e.* fresh to that individual; this, although derived from another individual possessed of life, during the digestive process has its capability continued of entering into the composition and sustaining the functions of the living body consuming it, until it in its turn shall have become effete; while any that may have become effete is not assimilated, but is discharged; and the organ chiefly containing these residua—as the spleen (and sometimes also the liver)—forms an article of food of very indifferent quality, and frequently causes great intestinal disturbance. In the case of the liver other effete matters may be also concerned. An excessive destruction, a diminished supply, or a faulty assimilation, will therefore have the same ultimate effects, and a condition of anæmia or of chlorosis will be the result. In some cases an increased supply remedies the mischief, in others the destruction must be checked, and again in others the powers of assimilation must be increased. It is generally conceded that a great destruction of blood-cells occurs in the spleen; in cases of ague we often observe congestive enlargement of this organ followed rapidly by anæmia. A short course of iodide of potassium, especially if taken early, is generally followed by subsidence of the congestion, diminution of the size of the organ, and a stop to the anæmia. The *modus operandi* is not the point in question, but that there is primarily congestion, that this is accompanied by destruction of the blood-cells; and this results in anæmia BECAUSE the iron is *discharged*, and fresh red corpuscles are not formed in sufficient quantity to replenish the loss; but when the congestion is *removed*, the destruction of blood-cells *ceases*, and the anæmia is soon replaced by the ruddiness of health. These are sequences which speak for themselves. Examples of the first case in chlorosis, and of the third in some of the complicated forms of phthisis, present themselves in every-day experience.

With the blood-cells and the alkaline carbonates of the serum are intimately connected the conveyance of the oxygen and carbonic acid gases, which are constant elements of the blood.

The nutritive portion of the blood may, therefore, be comprised under water, corpuscles, albumen, sugar, fat, oxygen, and salines.

We have before seen that the tissues to be nourished consist of cells lying closely applied to a series of plasmatic or nutritive vessels; in these tissues two acts are required to form by their combination the full nutritive act; the first consists in the exchange of a portion of the cell contents for a portion of the circulating plasma, and the second in the formation of the heat necessary to vitality by the direct oxidation of certain substances, either primarily brought into the tissues by the fluid itself, or else derived from the accomplishment of the first act. From the formation of the tissues, as before shown, there arises of necessity a great opportunity for the full action of the oxygen present from the retardation of the circulation, and this retardation is evident from the following calculation: The amount of blood which passes through the left ventricle in a given time is derived from the whole circulating apparatus in the same time; therefore, as much as the area of the extreme vessels exceeds the area of the left ventricle, by so much is the current through the extreme vessels slower than that through the left ventricle; if otherwise, the heart would be irregularly supplied, being sometimes completely empty and sometimes gorged, a condition of things not long compatible with life. And further as the area of the plasmatic vessels is still greater than that of the capillaries, and, as they form in a certain manner, courses out of the direct circulation, the rate of the current suffers still further retardation in them.

As the first act of nutrition consists of an interchange between the cells and the vessels, of portions of fluids holding certain matters in solution, it is of necessity that the molecular changes occur in the cell-fluid and cell-walls and not in the vessel-fluids. The parts to be nourished consist chiefly of C,H,N,O; their elements being no longer used in upbuilding tissues, but entering on a course of descending transitions, are finally expelled the system; the matters given off by the cells undergo a "dédoublement" or splitting into two portions or classes, of which one is rich in nitrogen, the other being poor in that element, or, according to Bischoff, being entirely destitute of it; this latter, under the influence of oxygen, forming CO_2 and HO, and thus generating heat. Hence nitrogenous food is absolutely essential to nutrition *in proportion sufficient to cover this loss*, while carbohydrates chiefly serve the purposes of animal heat. Where a due supply of nutriment is not afforded, the matters dissolved in the exosmosing fluids cannot be fully replaced from the vessel-fluids; and this decrease continues *pari passu* in the cell-fluids and in the vessel-fluids, the latter always retaining the predominance as long as any nutrient matter remains capable of being assimilated; and when an osmotic balance is reached the cells neither give off nor receive; life is, therefore, extinguished, and, after death, they are found pale and shrunk, but they are not dissolved, nor is there any trace that a single cell has been removed, from a muscle for instance, it is only the cell contents that have disappeared, *i. e.* their nitrogenous matters held in solution, a larger portion of the water still remaining and the muscles are said to be watery. (*Virchow's Arch.*, vol. xviii. p. 174.)

As soon, therefore, as osmose ceases, the maintenance of animal heat ceases, because after all the carbo-hydrates and fat have been consumed, nothing remains but this splitting of nitrogenous matters; and as soon as this is suspended, although there may be still inspiration of oxygen and absorption of it into the circulating fluid, there is no material on which it can act, as its action is neither on the nutrient fluid nor on the tissues, but on the matter given off from the tissues, which matter is replaced from the nutrient fluid. When, therefore, osmose ceases, the matter ceases to be given off, the action of the oxygen ceases from want of matter on which to act, heat ceases to be developed, and with this is the cessation of life.

It is obvious that as each of the tissues has a different composition, they must each require a different molecular deposit, and the series of rejected compounds will also differ; thus the compounds arising from the splitting up of the effete atoms of the cerebral tissue will differ from those of the muscular, these again from those of the osseous, and all of them from those of tendinous, ligamentous, cartilaginous, and parenchymatous structures, and in the proportion in which the vital activity in any one of these tissues exceeds that in any of the others, or the general activity of the whole, will those proximate principles be more abundant to which that particular tissue will give origin? At present, however, it would be premature to connect the formation of any principle with the molecular alterations of any organ.

It would also seem to follow as a legitimate conclusion from this, that, at least in some cases, a "*dédoublement*" may occur in the albuminous or nitrogenous element deposited at the time of its separation from the nutritive fluid in order to become a component of the tissues. Should this be actually the case, it must follow that there must be more than one nitrogenous product of tissue change; this especially appears when we consider the different composition of the different tissues, such as cartilage, muscle, cerebral, and glandular tissues, blood-corpuscles, &c. &c. We can hardly bring ourselves to conclude that all the effete nitrogenous matter in all these different tissues, and that both in formative and retrograde metamorphosis, enters into one single formation, sometimes, that is in the same tissue, giving off an excess of C and H, and at other times absorbing these elements to supply the deficiency. And as we also find that differently composed nitrogenous foods occasion corresponding differences in the nitrogenous excreta, it would seem logical to conclude that corresponding differences occur in the tissue-change of such tissues in the organism itself; thus we find that gelatinous food occasions a larger excretion of urea than the use of any other; it is, therefore, no strain of argument to conclude that the tissue change in the gelatinous tissues occasions a greater formation of urea than the tissue change in any other tissue; and, if such be the case with regard to the gelatinous tissue, to what especial principle does tissue change in each of the other tissues give origin? Shall we be also obliged to declare that creatine, creatinine, &c., are products of the decomposition of urea during the analysis? We can detect them in the muscular juice, *i. e.* in the food, and again in the excretions. Is it too much to suppose that they enter the blood stream only to be rejected by the proper secretion? and, if so, why does not the tissue change in the muscular tissue especially give origin to these principles? There are many substances which are absorbed into the blood stream from their osmotic or other physical properties, but being foreign to the organism are carried out of it again as soon as possible; such are excess of water, chloride of sodium, several salines of daily and common use; it is, therefore, only an extension of the same rule to apply it to those principles of retrograde metamorphosis which may be contained in any article of food. Again, the osseous tissue is the seat of a very active circulation, and, consequently, of as active nutritive changes. May not this tissue give extensive origin to formation of urea? The nervous tissue is especially rich in phosphorized fats, and the residua of its nutrition will have an especial reference to its composition. A clear and full comprehension of the elementary composition of each organ and tissue will give one link in the chain of its nutrition by showing what elements are especially required, while by knowing the proximate principles from which these elements are obtained, and by getting the especial results, if any, of feeding animals for some length of time, on such or such a tissue or organ, we may arrive at more definite conclusions on the subject; the examination of the blood-stream coming from such organ or tissue may yield only negative results, if the principle sought be present only in very small quantity.

The carbon, hydrogen, and oxygen given off in the splitting up of nitrogenous bodies, and arising from the direct absorption of non-nitrogenous matters, are given off chiefly as carbonic acid and water, sulphur and phosphorus as sulphuric and phosphoric acids, in combination with various bases. Amongst the nitrogenous formations that of ammonia, as an original formation, is a matter of much dispute, as a constituent of food it is but rarely absorbed, but as an element of excretion it is often met with; as ammonio-phosphate of magnesia it forms a frequent deposit in the urine, and is often met with in feces. The relations, however, between ammonia and urea are such that it is easy to suppose the latter may give rise to the former within as well as without the body. According to Lehmann, ammonia is nearly absent from healthy human urine. According to Voit, it is also absent from that of carnivora, urea being its sole nitrogenous component. In order to be enabled to transfer the teachings of comparative experiments to the human subject, it is necessary to observe them through all classes; and in nutrition in herbivora we have a very remarkable phenomenon, viz., the formation of hippuric acid; this not being peculiar to them, however, being also found in human urine. It is found, also, as an especial production after the use of a substance which contains no nitrogen, viz., benzoic acid, $C_{14}H_6O_4$; and after the use of some fruits, such as apples, plums, &c., as this acid is not found in the urine of carnivora, and under certain feeding is also absent from the urine of herbivora, and also from human urine, and as its contents of nitrogen is only one-half that of urea while its carbon is eighteen times as great, and its hydrogen three times as great, it would seem that its formation depended on the combination of the nitrogenous portion of the effete matter with that excess of carbon and hydrogen over and above what the oxygen present could convert into carbonic acid and water, which junction taking place in the nascent state, or while the various elements are rearranging themselves, it becomes a primary formation in the metamorphosis of tissue; in the same way as that an excess of carbon alone, or a relative deficiency of oxygen, occasions the formation of oxalic acid.

From the foregoing we may deduce the following law: that, as the food consists of carbon, hydrogen, oxygen, nitrogen, &c., in varying proportions, and as the various tissues contain the same elements, and also in varying proportions, it is of necessity—that as these elements are neither taken in nor thrown out in their elementary form (except oxygen, this, however, not being taken pure), but in various combinations as proximate principles, just in proportion to the differences in the food, and in the relative tissue-change in each of the tissues, will the proximate principles of the excretions vary, not only in the amount of each, but also in the very presence or absence of any one or more; and, therefore, the law of the formation of either one is not so much a law of the individual or species as a result of the circumstances in which the individual was then placed.

Bischoff and Voit have lately published a work on the Laws of Nutrition in Carnivora. They kept a dog for about fifteen months, and in this work they have given the results of their experiments. In order to give a better idea of the detail we will condense the argument contained in the first part of the introduction.

They first declare the whole of their superstructure to rest on the fact that all the nitrogen (except air) discharged from the body is a product of tissue change, and tissue change only; that the idea of oxidation of nitrogenous matter in the blood-stream is erroneous; and that the result of all the tissue change of nitrogenous tissues is urea, and urea only; and B. complains that his former work on this subject has not received the amount of consideration which it deserved. From the molecular decompositions are derived the various forces, of which two are especially noticed at some length: the force of motion, *i. e.* the internal motions, such as solution, absorption, circulation, and respiration; and the force of heat—these forces being correlated, and mutually convertible.

The author then argues that the motor forces are generated by the decompositions of nitrogenous matter under the influence of oxygen, perhaps under the form of ozone; while heat is given off by the decomposition of fat and the fat-formers. The amount of motor force generated is proportional to the mass of the organ, and its continuance to its replenishment by food; while the decomposition of both nitrogenous and non-nitrogenous is owing to the effects of oxygen, and the results in both carbonic acid, water, and urea may be considered as oxides. He then states the question: "If such be the decomposing influence of oxygen, how is it that the albumen of the blood is not consumed by it?" To this he replies that the combination of matter with nitrogen greatly reduces its oxidizability and combustibility, and that thereby, *i. e.* owing to its nitrogenous element, the albumen in the blood is protected; then he asks: How is it then that the nitrogenous *tissues* are decomposed under the influence of oxygen? The following view of tissue change contains the answer:—

The organ, the muscle, the cell are the material expressions of those molecular forces, which preserve their molecules in these separate forms. Their existence has, as a constant element, a continual interworking with nutritive material, *i. e.* plasma, and atmospheric oxygen. This interworking consists of a double attraction, which both plasma and oxygen exert on this or that organ, and is produced only by the simultaneous co-operation of both; we may comprehend it best under the idea of a pressure on the part of the plasma, and an attraction on the part of the oxygen, which produce a fresh molecular arrangement in the organ. Neither oxygen nor plasma are sufficient separately; both are required to produce these effects.

The decomposition being always the result of the co-operation of all three of these factors, it is always directly proportional to the mass of these factors, *i. e.* of the organ, the plasma, and the oxygen.

It is increased when the bulk of the organ is large or increasing; it will decrease when the bulk of the organ is small or decreasing; being, however, within certain limits independent of the quantity of the plasma or of the oxygen.

It will increase when the bulk of the plasma increases, even if the bulk of the organ should not increase, and the action of the oxygen should not increase, but decrease.

It will decrease if the bulk of the plasma decreases; but it will in this case even exceed the quantity proportional to the plasma, if the bulk of the organ and the quantity of the oxygen be large.

It will also increase if the quantity of oxygen be increased, even although the quantity of the organ or of the plasma be not greater, but less; it will decrease if the quantity of the oxygen be diminished directly or indirectly, that is, if a portion of the oxygen be otherwise combined.

It is evident, therefore, that decomposition is always a complicated product of the operation of these three factors, and can only be understood by a careful examination of all three.

The bulk of the organ will be dependent on the relation which its replenishment by the food, *i. e.* the plasma, bears to its decomposition; it will increase or decrease, or remain stationary in bulk, just as the plasma brings more or less fresh material, and as the decomposition is more or less active, or the quantity of oxygen is increased or diminished, or otherwise absorbed.

By these decompositions force is liberated, and as heat is provided for by the decomposition of non-nitrogenous material, so by that of the nitrogenous portions motor force must be supplied; while this is without question required for the keeping up the before-mentioned internal motions.

If we consider an animal without food, and in a state of rest externally, it is then living on its organs and blood constituents; it presents an amount of decomposition, depending on the bulk of its decomposing organs, and the quantity of albumen and absorbed oxygen in its blood. The force which is thereby liberated is used for the uninterrupted maintenance of the internal motions, which are absolutely necessary to its existence; and it is proportional to the bulk of nutritive material moving in this condition, which, according to the bulk of the organs, gives the proportion of the decomposition on which the amount of disposable force is dependent, most strikingly exhibiting the harmony between cause and effect.

As the decomposition is the result of the mutual operation of the organ, plasma, and oxygen, and as by it the force is liberated which is necessary for the internal motions, this is proportional to the amount of plasma to be moved; and this last is again, the influence of the organ and of the oxygen remaining the same, the measure of the decomposition.

When we give an animal food the amount of the blood of the plasma is increased, therefore also the amount of the decomposition is greater, and consequently a greater amount of force liberated, on which the movement of the plasma is entirely dependent, the bulk of the organ being considered.

But with this view of the case the animal would still be in a fasting condition, and the loss of its organs would not cease, because the newly taken food would only yield the force necessary to provide for its own movement.

But herewith is connected at each introduction of food a diminished operation of the oxygen on the decomposition in the organ.

While the primary result of the decomposition of nitrogenous matters is the supply of force necessary to internal movements, there are subsequently formed products, having reference only to the development of heat. The greater the decomposition from increased supply of food, the greater the amount of these products of decomposition, and therefore the more oxygen will be absorbed by them. But the disposable quantity of oxygen in the blood is limited. The more therefore is used as above, the less remains for the primary decomposition, of which it also is a factor. The influence of the bulk of the food on the decomposition bears an inverse proportion to the operation of the oxygen on it. When the former is increased the latter is diminished, from the increased amount of decomposition products; and when the former is diminished the latter is increased, because less is then absorbed by the fewer decomposition products. Both influences are not developed in an equally strong degree, consequently they do not generally act equally strong on the decomposition; but they are developed, and act only proportional to one another. In proportion as the supply of plasma increases, in the same proportion the operation of the oxygen is diminished. The general result being that with a stronger flowing plasma the relative decomposition of the organs is always less. So long, therefore, as supply and decomposition are not in equal proportion, the portion which the organ loses by its decomposition will gradually decrease with the increase of the supply, until an equilibrium is reached in which the supply entirely replaces the decomposition in the organ; and if the former be still increased, then the possibility of deposition, and consequent increase of the organ is induced. But in order that this should continue, the supply must be still further increased. For as soon as the mass of the organ increases, the decomposition is consequently increased, and the same amount of food yielding now no longer an excess, indeed not much longer an equivalent, but very soon a relative deficiency, a decrease of the organ again ensues. In this manner, by increasing the supply and consequent diminution of decomposition from absorption of oxygen, by increased decomposition products, an increase of the organ will ensue, until the operation of the oxygen is so much reduced, and the decomposition sinks so low, that the force necessary for the assimilation and movements of the food can be no longer supplied. The animal then ceases to eat; but as the decomposition is continued, whilst the supply is diminished, the equilibrium is soon re-established, and sufficient force is soon generated for a fresh movement and assimilation of the food.

The same effect which is produced thus indirectly by the increased amount of decomposition products is brought about directly by the entrance of oxidizable substances—as fat, sugar, and alcohol—into the blood; which, by absorbing the oxygen, lessen the amount of the general decomposition. This will be always somewhat proportional to the supply of albuminous plasma. Is this very limited, as the result of an entire want of nitrogenous food, then the decomposition will be diminished in proportion to the quantity of fat and sugar consumed; it will, however, from the circumstances mentioned above, always remain sufficiently great to supply the forces necessary to the maintenance of the internal movements. This internal force is but little influenced by the taking of fat or sugar; for, as these matters pass in extremely small quantities from the digestive tube into the blood, they will be continually burnt in the blood as they arrive, and thus they do not require the same amount of motor force as the nitrogenous substances, which must permeate the entire organism, to undergo their decomposition in the minute tissues. The decomposition of fat and sugar develops but little force; there is, however, but little required; and thus, although fat and sugar are absorbed into the blood, the proportional relations between decomposition and motor force are not disturbed.

If, however, in addition to fat or sugar, nitrogenous food is introduced into the blood, the same conditions and results are developed, as before stated. The increased supply of plasma increases the decomposition. That occasioned by the increase of the plasma is added to that of the fasting condition, and at first the increase of the supply will not lessen the consequent decomposition and wasting of the organs; indeed, each continued increase of the supply will, as before, produce a continual increase of the decomposition, and a continuance of the waste of the organs, in order to liberate the motor force required by the increase of the plasma. But the intervention of fat or sugar will place an earlier limit to this proceeding. From the use of them less oxygen will be free to maintain the decomposition by its influence, and consequently the limits will be the earlier reached, where, by continuance of supply, the decomposition will be counterbalanced, and finally deposition be induced. This period, as with the use of nitrogenous food only, is reached but gradually; for here also, as the plasma and decomposition increase, the decomposition products are increased, and they absorb, in addition to the fat and sugar, a larger portion of the oxygen; whence it shortly happens that the decomposition is gradually so much lessened that the organ gives off no more from its constituents, when, in this respect, an equilibrium is produced; and if the supply be still further increased, deposition ensues; and, indeed, as before said, so much the sooner, as the operation of the oxygen is lessened by the presence of fat and sugar.

The necessary limits are arrived at, as in the preceding sketch, partly by the limited capability of absorption of fat and sugar, or else by circumstances which prevent their great accumulation in the blood, the fat being removed by deposition, the sugar by the urine. There is also a limit to the operation of these substances, arising from an increased affinity on the part of the oxygen to the decomposition products of the nitrogenous tissues than to the fat or to the sugar taken with the food; therefore the decomposition products and the other oxidizable constituents of the blood are always burnt or oxidized the first. Another circumstance which may occur with relation to fat and sugar may be, as above mentioned, that these substances do not consume so much motor force as the albuminous bodies; were the case otherwise, the decomposition would not be lessened by their use, since then the force required for their movement would be wanting.

It will be seen, in the course of the experiments, that the operation of the fat may be so developed, as aforesaid, that, when added to an entirely nitrogenous diet; in from one-fourth to one-fifth of the entire quantity of food necessary, it produces an equilibrium between supply and decomposition; and if from one-third to one-fourth, it renders deposition possible. If the nitrogenous food be then increased, it is consumed, because its increase produces an increase in the decomposition, even in the presence of fat. The oxygen does not combine with the fat, but with the decomposition products of the nitrogenous organs, for which it has a greater affinity, and the fat is deposited. The motor force being supplied by the decomposition of the nitrogenous material, the deposition continues, and the decomposition being only proportional to the motor force required, with the increase of food the decomposition products after a time absorb all the oxygen, all the fat is deposited, and the decomposition itself ceases from want of oxygen, the motor force fails, and the animal again ceases to eat.

The subject of volitional movement is next considered, the animal having been hitherto supposed to be in a state of rest. The starting-point in the whole explanation lies here again in the position that in the organism no force is supplied to produce motion but one which is liberated by decomposition of the respective organs. According to the present state of our knowledge, it is impossible that the molecular force to which the organism owes its structure and composition can be directly effective as a motor force, but there must always be first a decomposition of the material of which the moving organs themselves consist; this molecular force does not forsake the matter and change into motor force, and relinquish the matter to other forces, but the reverse. The arrangement of the molecules of the matter is the operation of its molecular force; it brings and maintains the molecules in this arrangement, and to this its operation is limited. Should the matter be applied to other uses, as motor or calorific purposes, then the molecules of the organic matter must be driven by other molecular forces into another arrangement, and then a transfer into motor or calorific force may occur. If we, therefore, wish to produce any motor force in the organism, it is necessary to cause a decomposition in the material of that organ which performs the motion, and our explanation of the circumstances of motion must proceed from an explanation of the circumstances of decomposition. It is now beyond doubt that the nerves exert this influence. In consequence of their action, whether voluntary or otherwise, the decomposition of the organ is produced, and force is thereby set free, which now manifests itself in movement. We doubt not that this action of the nerves, this influence which they exert on the decomposition of the organ in the imparting of motion, consists, as it were, in a shock, which alters the arrangement of the molecules of the organ. We are of the opinion that this motion in the nerves manifests itself, among other things, in an altered grouping of those electric molecules of the nerves which we have learned from the admirable investigations of Du Bois, when the nerve is in a state of activity.

The nerve is thus a fourth factor, which operates on the decomposition of nitrogenous tissues, besides the oxygen, the plasma, and the bulk of the organ itself; but while the action of the three latter is uninterrupted, that of the nerves is temporary, subject to the influence of the will, and appears, therefore, to a certain degree, only as one increased according to circumstances and intention. Yet it is plain that the force which is hereby liberated is used only in volitional movements; and if, therefore, the force necessary for the uninterrupted continuance of the internal movements must not fail, then the decomposition of the tissue elements, or of the elements of their nutrient supplies, must in a corresponding degree be increased.

It necessarily follows that, when voluntary movements are produced, the relations of all the above-mentioned factors must vary. When the supply of food is not sufficient to cover the tissue loss, the body being at rest, an additional loss will be incurred in consequence of voluntary movements, and a nourishment which would in the former case be sufficient to cover all loss will now be insufficient, and the point at which deposition would occur be still further removed. The capability of receiving and digesting food will be also increased, for we know that these movements accelerate the respiration, and increase the absorption of oxygen, which will cause a greater decomposition than in a state of rest.

The further consideration of this subject, and of reflex motions, is beyond the range of the present paper. The author only wishes to show how they harmonize with his explanations of nutrition.

It has been already mentioned that animal heat is undoubtedly the result of the decomposing effects of atmospheric oxygen in certain organic matter —as fat, starch, and sugar—part of which, as fat, is a constituent of the body, part, as fat and sugar, are found in the blood, as derivatives of the food. The fat, which is already a constituent of the body, and is contained in small droplets within nitrogenous cell-walls, is less easily accessible to the influence of oxygen than that distributed through the blood, and therefore the attraction of the oxygen will vary accordingly.

It is not to be supposed that heat can be developed *directly* from the decomposition of the nitrogenous tissue elements, because, if such were the case, the application of nitrogenous food and tissue elements to the production of motion would be impossible. But it does not necessarily follow that, after this primary decomposition has taken place, the residuary elements may not be in part still further decomposed by the oxygen, and from this secondary decomposition heat be derived; this is, on the contrary, certainly the case, because these substances are finally expelled as oxides. It is thus indubitable that heat is derived from the further oxidation of decomposition products of nitrogenous matters, both of the body and of the food. The relative affinity between the oxygen and the former of these is best seen in a condition of hunger.

The proportion in which the tissues are decomposed and their products still further consumed, and in which the fat of the body is also invaded, shows the degree of the affinities which are here in operation. It is in this case, however, most important to remember that they are not perfectly represented; that is, although the oxygen has a much greater affinity to the fat than to nitrogenous substances, the decomposition of these latter is not prevented, the oxygen not combining entirely with the fat; the causes of which are evident—partly through the liability to decomposition of nitrogenous tissue elements, through the pressure and attraction of the plasma, partly because the fat is not distributed through the blood, but is contained in nitrogenous cell-walls. When, however, this is not the case, as when we feed an animal fat, so that the fat is found in the blood, nitrogenous tissue is always decomposed, a proof that even here the attraction of oxygen to it and its decomposition products is greater than even to the free fat in the blood.

The oxygen, therefore, first produces the decomposition of nitrogenous matter with the assistance of the plasma, and then, by further combination with decomposition products, develops heat. What oxygen remains above this operation, when the resistance on the part of the nitrogenous tissue is increased, combines with the free or deposited fat, and sooner with the former than the latter.

But as the resistance of the nitrogenous tissues to oxygen is dependent on the bulk of the organ and the quantity of plasma, and is diminished by the increase of this latter, it is evident that the amount of oxygen capable of uniting with the fat will depend on the bulk of the nitrogenous tissues, and principally on the amount of the plasma; for as the latter increases, the decomposition increases, decomposition products are more abundant, these absorb more oxygen, and less remains for combination with the fat. This may continue until all the oxygen is consumed by the nitrogenous elements of the tissues and food, and all the heat is developed from these decomposition products. The fat is then no longer consumed, even when it is free in the blood; it is therefore deposited. Whether sugar, in such cases, is converted into fat and deposited, we must at present leave undecided, since we cannot, as in the case of fat, speak of its general relations and attractions towards oxygen; but, from our experiments, we may here remark that in carnivora the circumstances are never such that all the sugar is either consumed, or excreted in the urine.

There is thus a condition in the nutrition of an animal when the whole of its heat is derived from its nitrogenous food, yet never from its direct oxidation in the blood, but always as a result of the decomposition of the nitrogenous tissues. There is, therefore, no "luxus consumption" or oxidation of albumen in the blood, as Frerichs and Schmidt affirm. But since this large consumption of nitrogenous tissue and food in the body of an animal, whereby all its heat is also supplied, is not necessary to its existence since the force which is thereby developed is used only for the movement of this mass of food, the heat which is thereby formed as a secondary product is much preferably produced by the use of other matters, as fat and sugar; and this excessive use of flesh is a great "luxus consumption," which can and ought to be prevented by the due use of non-nitrogenous substances.

We thus see the principles which have been deduced from the various experiments detailed more fully in the work. The question as to whether urea is or is not the sole nitrogenous product of tissue-change in carnivora lies at the foundation of all his arguments, and of all his experiments also. The dog, on which these experiments were carried on, was fed in various ways, having been first examined in a fasting condition to obtain a basis for further investigations. The dog was carefully weighed every morning, as were also his food, drink, and excrements, and his urine measured; this last he was trained to pass every morning into a glass vessel. It was then tested for urea by Liebig's method of trituration by nitrate of mercury, and for sulphuric acid by baryta, the nitrogenous contents of the food, and also of the excrements were also ascertained, and the calculation made as to the gain or loss of tissue accordingly; the amount of fat or water given off or deposited was calculated from the amount of oxygen inspired, and from the amount of animal heat liberated by the combustion of the carbon and hydrogen. The experiments were conducted with the greatest care, and deserve attentive consideration.

The first series of experiments are on the tissue-change in the fasting condition.

From October 19 to 25, the dog was kept without food, but on the 23d he drank 63 grm.[1] of water. He weighed, on Oct. 19, 33,310 grm., on Oct. 25, only 30,330 grm., he thus lost 2980 grm. He excreted 1130 c. c. of urine weighing 1186 grm., which contained 121.558 grm. of urea, equal in nitrogen to 56.73 grm.; this represents 1668 grm. of flesh, which must have been derived from his own body; besides this, he lost 1312 grm. of fat or water, or of both.

Doubtless this loss was fat only, for if it were water the material indispensably necessary for respiration and the maintenance of heat would be wanting. According to Reynault and Reiset, a dog of this weight would consume daily about 250 grm. of carbon, and 900 grm. of oxygen. If the dog had had only the carbon from the above calculated flesh, 1668 grm., it would not have amounted to 40 grm. in the 24 hours; while reckoning the remaining loss as fat, he would have 180 grm. of carbon as his supply. So with this amount of flesh he would have had only 100 grm. of oxygen daily, while the additional fat would give him 644 grm. The well-known fact that fasting animals lose their fat argues further in favour of the loss being fat, while there is no ground to suppose that the dog would give off water while as much water as he desired was at his disposal.

But the calculation of the excretion from the kidneys, skin, and lungs, show that the dog needed no more water than would be formed from the flesh and the hydrogen of the fat.

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[1] In all these experiments grm. is used to signify grammes, the French decimal weight of 15½ grs. nearly.

The following table gives us the calculation:—

INGESTA.					
FOOD.	Water.	N.	C.	H.	O.
1668 grm. of his own flesh .	1266.0	56.73	208.8	28.86	85.9
1312 fat tissue with 1128.3 of fat	183.7	...	891.3	124.10	112.8
Water drunk	63.0				
	1512.7	56.73	1100.1	152.96	198.7
EGESTA.					
1130 c. m. urine . . .	1048.0	56.73	24.4	8.20	32.6
There remains for lungs and skin	464.7	...	1075.7	144.76	166.1

The 144.76 H. are equal to 1302.8 water, therefore he excreted by the lungs and skin 1767.5 water, and 1075.7 grm. of carbon.

In order to prove the correctness of our calculation founded on this consumption of nitrogen we use the computation of the relative loss by the skin and lungs, as a proof thus—

The dog consumed from his body	2980 grm.
" " water	63 "
	3043 "
He evacuated 1130 c. c. of urine . . .	1186 "
There remain for skin and lungs	1857 "
Our reckoning above gives	1851 "

The amount of animal heat generated gives us another proof; for every 1 grm. of carbon 8086 units, and for every 1 grm. of hydrogen 34,462 units of heat are generated according to the researches of Von Favre and Silbermann; but as the 166.1 grm. of oxygen would combine with 20.7 grm. of the hydrogen, there would be left 124.06 grm. of hydrogen and 1075.7 grm. of carbon to be oxidized; these would yield 12,976,466 units of heat, or for each 24 hours 2,162,744 units.

A second experiment of three days yields similar results. A third of seven days immediately following a seven days very high feeding with flesh and fat agrees in general with the others, with some variations arising from the different condition of the dog. A fourth and fifth relate to single days of fasting, agreeing closely with one another and with the general results.

The second series, containing fourteen experiments, relate to feeding on flesh only.

The flesh was fresh lean beef very carefully freed from fat, cartilage, bone, &c.; this contained, as shown by numerous analyses, only one per cent. of fat.

The first seven experiments cover nineteen consecutive days, in which the dog was fed for seven days on 1800 grm. of flesh, which was reduced every third day until it reached 176 grm. only, as shown in the following table:—

Table of Flesh Feeding.

DATE.	Weight, grm.	Food, grm.	Water, cm.	Urine, cm. and grm.		Urea, grm.	Feces, grm.
		Flesh.		Cub. cm.	Grm.		
Nov. 9	34410	1800	213	1751	1798	86.850	
10	34100	1800	5	1428	1486	118.524	
11	33990	1800	310	1599	1663	131.756	17.6
12	34020	1800	137	1313	1372	120.796	
13	34200	1800	340	1401	1465	131.694	16.2
14	34460	1800	18	1185	1244	123.714	
15	34610	1800	120	1213	1272	123.626	
16	34850	12600	1143	9890	10300	847.059	
16	34850	1500	10	990	1039	108.50	163.9
17	34810	1500	10	1003	1055	108.12	
18	34910	3000	20	1993	2094	216.62	163.9
18	34910	1200	...	830	872	89.81	
19	34910	1200	...	809	851	87.37	
20	34930	2400	...	1639	1723	177.18	
20	34930	900	...	571	705	69.784	
21	34780	900	...	615	647	65.805	
22	34710	1800	...	1186	1352	135.589	
22	34710	600	...	465	489	49.848	
23	34490	600	...	450	474	48.150	
24	34320	1200	...	915	963	97.998	
24	34320	300	...	320	337	32.640	
25	33970	300	...	317	333	32.651	
26	33660	600	...	637	670	65.291	
26	33660	176	...	274	288	27.400	
27	33270	176	...	258	271	26.212	
28	32850	352	...	532	559	53.612	

December 1, the dog fasting, he discharged 24,213 grm. of feces.
To every 100 grm. of flesh fed there correspond nearly 1.85 grm. of feces.

In examining the first experiment of seven days there were 33.8 grm. of feces remaining in the dog from his previous food, and as the quantity of meat fed would yield 233 grm. of feces, the dog gained only 241 grm.

The 12,600 grm. of flesh contained 428.4 nitrogen. The 847.059 grm. of urea contained 395.32 grm. N. The 233 grm. feces were composed of 44.4 per cent. of solids, or in the whole of 103.45 grm. of solids and 129.55

of water. The solids contained 6.5 per cent. of nitrogen. The urea and feces contained, therefore, 402.04 grm. N., showing a gain of 26.36 N., equal to 775 grm. of flesh. These were deposited; but as the dog gained only 241 grm. he must have given off 534 grm. of fat or water. It was doubtless water, because the amount of carbon and hydrogen in the 1800 grm. of flesh were sufficient for the necessities of respiration, and because for the first four days he lost weight and the urine was very watery.

The following calculation is appended :—

INGESTA.					
Food.	Water.	N.	C.	H.	O.
11,825 grm. of flesh . .	8975.17	402.05	1480.49	204.57	608.99
Water drunk	1143				
Water given off . . .	534				
	10652.17				
EGESTA.					
9890 c. c. urine . . .	9323.00	395.23	169.41	54.41	226.91
233 grm. feces	129.55	6.72	44.94	6.69	13.22
	9452.55	401.95	214.35	63.10	240.13
There remain for skin and lungs	1199.62	...	1266.14	141.47	368.86
141.47 H. = ...	1273.23				
	2472.85				

The proof—

The dog consumed in flesh	12,600 grm.
" " water	1,143 "
	13,743 "
He excreted in 9890 c. c. urine	10,300 "
Feces	34 "
Increase in weight	440 "
	10,774 "
There remain for skin and lungs	2,969 "
Our reckoning gives	2,977 "

From this we learn that the 1800 grm. of flesh were sufficient to nourish the dog in all respects; that at first, when the dog had been previously fed on bread, he was poor in nitrogenous elements, and at first he lost weight by exchanging other matters which he gave off for flesh which he deposited. The respiratory requirements and the heat were not fully met by the above calculation; the flesh consumed would give only 1,932,043 units of heat, while we have seen that in the fasting condition 2,200,000 were about the minimum, wherefore he must have lost, during the first day, about 80 grm.

of fat, depositing 608 grm. of flesh according to the difference between the nitrogen taken in the food and excreted in the urea. A great excretion of water took place on the first three days, in which the dog continually lost in weight. On the first day he must have lost 838 grm. of water, the body having been very full of water from the previous feeding with bread.

We see also that the three chief ingredients of the body, the nitrogenous tissues, the fat, and the water, bear certain proportional relations to one another, and to the alterations in the weight of the body.

The calculations for the rest of this series can be easily made from the accompanying table; they show no variation from the general principles laid down. The remaining seven experiments under this head relate to large quantities of flesh food, the results, however, are similar in all respects to the above.

The third series of nineteen experiments were made with feeding flesh and fat, and fat alone; the flesh was prepared as before; the fat was pure melted butter.

In the first experiment the dog was fed 150 grm. flesh, and 250 grm. fat for ten days, in which he lost only 161 grm., but as he gave off 830.3 grm. nitrogenous tissue he must have deposited 669.3 grm. of fat or water, or 575.6 grm. fat-tissue with 93.7 water.

In a thirty-one days' feeding with 500 grm. flesh and 250 fat, the dog gained 4543 grm., composed of 1794 grm. flesh, 2364.14 fat-tissue, and 384.86 water.

Several experiments follow of variable quantities of flesh combined with 250 and 150 grm. of fat; thus, 1000, 1500, 1800, 2000 grm. of flesh with 250 grm. fat, and 1500, 1000, 700, and 400 grm. of flesh with 150 grm. fat; the first set show that the dog deposited flesh and fat, and continually gave off water; in the second set, although the food continually diminished in quantity, the weight of the body remained nearly the same, the dog continually giving off his nitrogenous elements, the N. in the urea being always more than that contained in the food, he therefore deposited water. But the action of the fat in preserving the nitrogenous tissues is shown in the fact, that, while the food sank from 1500, as above, to 400 grm., the nitrogenous decomposition increased only from 8 to 23, 77, and 81; the effects of the same quantity of fat were seen most strongly when combined with the smallest quantity of food, because the larger quantity of food would of itself cause an increased decomposition; with this would arise an increase of decomposition products, which, by absorbing oxygen, would render a deposition of fat necessary; but as the amount of the food was lessened there was sufficient oxygen not only for all the decomposition products and the fat, but also for a certain amount of the constituents of the body. When the fat began to be insufficient to render a deposit of flesh or fat possible the dog began to drink water, which he had before refused.

In three days' feeding with 500 grm. flesh and 200 grm. fat per day, the dog gained 304 grm., the N. of the flesh, and of the urea and feces, equalled one another, the deposit would be 261 fat, 48 water.

In three days' feeding with 500 grm. flesh, and 300 grm. fat, he gained 354 grm., as the N. excreted was less than that contained in the food the gain was 132 grm. flesh, 190.92 fat, and 31.08 water.

Four days' feeding with 500 grm. flesh alone showed a loss of 754 grm., which, from the excess of N. excreted, should be divided into 88 grm. flesh, 572.76 grm. fat, and 93.42 water.

Three days' feeding with 1500 grm. flesh and 350 fat caused a gain of 962 grm., of which 159 grm. were flesh, 690.6 fat, and 112.4 water.

Two days' feeding with 330 and 350 grm. fat only showed a loss of 100 grm., but as the N. excreted was considerable, while none was taken in the food, the calculation would be loss of flesh from the body 410 grm., deposit of fat 266.6, of water 43.4 grm., the loss of nitrogenous tissue exceeding the loss of total weight by 310 grm.

The fourth division comprises feeding with flesh and sugar, and sugar only, and contains eleven experiments; the sugar used was grape and milk sugar.

The first experiment is shown in the following table:—

DATE.	Weight.	Flesh.	Sugar.	Water.	Urine.		Urea.	Feces.
					C. C.	Grm.		
Nov. 16	28670	150	100	415	190	197	13.680	201.8
17	28610	150	150	95	185	193	13.690	...
18	28500	150	250	107	156	164	13.104	...
19	28520	150	350	185	148	156	13.616	141.4
20	28520	150	350	200	240	248	13.440	...
21	28620	150	350	154	260	268	13.000	103.6
22	28480	900	1550	1216	1179	1228	80.530	446.8

Calculating the relative proportions of feces the dog lost 117 grm. He excreted N. equal to 444 grm. flesh more than he received, and must have deposited water to the amount of 327 grm. The feces consisted of 271.39 water and 102.41 solids, but contained no sugar.

In a second experiment the flesh and sugar were respectively 750 and 150, 500 and 200, 300 and 250, 300 and 250, 150 and 300, 200 and 300, the first number being flesh, the second sugar; the dog remained of the same gross weight, but, calculating the feces derived from the food and still retained, he lost 172 grm. He excreted N. equal to 779 grm. flesh more than he received, but, as his weight was only 172 grm. less, he must have deposited 607 grm. of water. It could not have been fat, because the carbon necessary for excretion by the lungs and skin would have been deficient.

With large quantities of flesh and sugar he gained in weight, thus with 2000 grm. flesh, and 200 of grape sugar, he gained 193 grm.; but, as he deposited N. equal to 320 grm. of flesh, he must have given off 127 grm.

water. With 2000 grm. flesh, and 100, 200, and 200 of milk sugar, he gained 546 grm. He deposited 600 grm. flesh, and gave off 54 grm. water.

A series of five experiments give the following results:—

Fed on		The consumption was		
500 grm. flesh.		564 flesh.	161 fat.	
500 flesh.	250 fat.	557 "	175 "	
500 "	100 sugar.	537 "	151 "	100 sugar.
500 "	200 "	500 "	76 "	200 "
500 "	300 "	466 "	34 "	300 "

From this we see the nitrogenous decomposition was greatest with flesh alone; that fat reduced this less than sugar; that the influence of the sugar was proportional to its quantity; that the fat besides reducing the nitrogenous decomposition caused a saving of the fat of the body, although 14 grm. more of the fat fed were consumed than previously of the body fat; that the sugar took the place of the body fat and of the fat in the food, yet 300 grm. of sugar were not sufficient to prevent the consumption of some of the body fat; 100 grm. sugar saved 20 grm. body fat, and 24 grm. of the fat of the food; 200 sugar, 85 and 99; and 300 sugar, 127 and 144 of the body fat and food fat respectively.

It follows that fat and sugar have an inverse influence on nitrogenous decomposition and the respiratory process. The fat, from containing two and a half times as much carbon and hydrogen as sugar, is more effective in the respiratory process, while sugar is more powerful in reducing nitrogenous decomposition. The fat and sugar both act by absorbing oxygen, and so reducing its influence. According to their composition the fat should be more effective than the sugar; the contrary, however, is the case, because the sugar more readily combines with the oxÿgen, absorbing it directly, while the fat has to take part in the general tissue decomposition previously. The action of the sugar is more direct and immediate, and lessens the nitrogenous decomposition more than fat from not requiring so much motor force.

In one experiment of two days, in which the dog was fed with 370 and 500 grm. of grape sugar, he lost 368 grm. He excreted N. equal to 494 grm. of flesh, and therefore deposited 126 grm. water. In comparing this with an experiment in which he was fed on fat only, being in both cases of the same weight and in equally good condition, we observe that in this case he consumed, daily, 247 grm. flesh and 430 grm. sugar; in the other, 196.5 grm. flesh and 196.8 grm. fat. Thus 100 grm. sugar reduced the nitrogenous decomposition as much as 100 grm. of fat, or, considering their respective proportions of carbon and hydrogen, two and a half times more.

The next division treats of feeding on flesh and starch, and starch alone.

The starch was mixed with fat and salt into a kind of cake, which was baked. This the dog would eat only in small quantities, and for a short time; to have given it in larger quantities it would have been necessary to have crammed him.

The first experiment was continued for eleven days, in which the same of flesh, 176 grm., was given daily; the starch and fat varying from 100 to 364 for starch, and from 9.1 to 29.6 for fat. The total loss in weight, after calculating the feces, was 33 grm. He excreted nitrogen in excess, equal to 484 grm. flesh, and therefore deposited 451 grm. of water. It is evident that 176 grm. flesh, with any quantity of starch, was not sufficient to cover the nitrogenous decomposition, the average amount of which was 206 grm. daily; although the starch had considerable influence in reducing it, as may be seen by comparing the loss when 176 grm. flesh alone were used. The quantity of starch, however, exerts some, though only a slight, influence on it, for the amount of urea was less when the greatest quantity of starch was fed, and the reverse. With 150 grm. starch 66.5 grm. flesh were given off, with 364 grm. starch only 23 grm. flesh; so with 150 grm. starch 96 grm. of body fat were given off, with 364 grm. starch only 18.

In a second experiment of eleven days the flesh was reduced from 700 to 150 grm., while the starch was increased from 150 to 430 grm., and the fat from 11.5 to 20 grm. The dog, however, lost 335 grm. in weight; he excreted nitrogen in excess, equal to 1,309 grm. of flesh, and therefore must have deposited 974 grm. water. In a five days' feeding, with 2,000 grm. flesh daily, and 200 grm. of starch for two days and 300 for three days, with about 5 grm. of fat daily, he gained in weight 1,287 grm., of which 1,041 were flesh and 246 water. A five days' feeding with 500 grm. flesh, 250 fat, and 250 sugar, resulted in a gain of 639 grm.; but as he excreted nitrogen in excess, equal to 295 grm. flesh, he must have deposited 934 of fat or water, or both—thus, 803.24 fat, and 136.76 water.

When fed for three days with 100, 200, and 360 grm. of starch, with 22, 23, and 40 of fat, he lost 90 grm., and gave off nitrogen equal to 527 grm. of flesh, and therefore deposited 437 grm. water. Two days' feeding with 450 grm. starch and 19.7 of fat resulted in the weight of the dog remaining the same; but as he excreted 334 grm. of flesh in nitrogen of the urea, he must have deposited 334 of water.

The next division relates to feeding with bread only, with two experiments. The first, of six days' feeding with from 678.8 to 999.7 grm. of bread, which were again reduced to 730 grm., showed a loss of 296 grm., with an excessive excretion of nitrogen, equal to 924 grm. flesh, with consequent deposit of 628 grm. water.

In forty-one days' feeding with bread, in very variable quantities, just what he chose to eat, from 1,091 to 263 grm., the dog lost 531 grm.; he excreted nitrogen in excess, equal to 3,717 grm. flesh, and consequently deposited 3,186 grm. water.

The seventh and last series of nine experiments relate to feeding on flesh and gelatin, fat and gelatin, and gelatin alone.

The gelatin used was the fine French glue, in thin, clear yellow plates; this was dried in an air-bath, and then weighed; then covered with hot water and allowed to stand all night, and again weighed, when the contained water was estimated. The dog ate this jelly at first in small quantities, and very readily when mixed with flesh. The quantity of flesh fed was about equal to the nitrogenous decomposition in the fasting condition. The results of the first experiment are shown in the following table:—

DATE.	Weight.	Flesh.	Glue.	Water.	Urine.		Urea.	Feces.
May 1	40500	1100	100	160	1084	1133	110.57	...
2	40400	1200	100	93	983	1032	112.06	...
3	40430	800	200	257	957	1005	112.46	...
4	40380	400	300	288	895	937	110.98	...
5	40110	400	300	543	916	960	100.92	...
6	40000	3900	1000	1341	4835	5067	555.99	...

Calculating the feces, the loss in weight is 590 grm. He received in flesh and glue 273.1 nitrogen, and excreted in the urea and retained feces (90 grm.) 262.0 nitrogen, being 11.02 grm. less nitrogen than he received; these are equal to 324 grm. of flesh, which he deposited; but as he was 390 grm. lighter, he must have given off 914 grm. water and fat.

On the first day the nitrogen received and given off was equal; there was also some fat given off to support animal heat, and some water.

On the second day 76 grm. flesh were deposited, and fat was given off as before.

On the third day 87 grm. flesh were deposited, but he lost 131 grm. in weight; he must, therefore, have given off fat and water.

On the fourth and fifth days he deposited 100 grm. of flesh in each, but gave off on the fourth day less fat and more water, on the fifth more fat and less water.

It is evident from the results of this experiment that the gelatin lessens the nitrogenous decomposition, and the necessity for nitrogenous, *i.e.* flesh, diet. We thus see that the use of 400 grm. flesh, which had previously caused no deposit of flesh, even with the addition of fat, when combined with 300 grm. of glue occasioned a considerable flesh deposit, although at the same time fat was given off; and this is rather remarkable, because its conversion into respiratory material cannot account for it, since it contains so much oxygen that it can yield but little carbon and hydrogen for further combustion. The feeding of fat, as we have seen, protects only a small amount of the nitrogenous food from decomposition, and thus promotes its deposit. Glue must have a special action, and it is manifest that its quantity is very important, for a thrice larger quantity of glue, with a thrice less quantity of flesh, produced a considerable deposit, which did not occur when the proportions of flesh and glue were reversed. We must, therefore, consider that the glue is assimilated, and performed a part of that work for which the albumen of the food would have been otherwise employed, so that a portion of this latter could be deposited.

In the second experiment, of three days' feeding with 200 grm. of flesh and 200 of glue daily, the total loss was 1,405 grm.—735 grm. flesh, 330 fat, and 341 water.

. A third experiment, of two days' feeding with 200 grm. flesh and 300 glue, gave as the loss 353 grm.—154 flesh, 190 fat, and 9 water.

This last experiment presents one point of great interest; for as we have just seen that when 200 grm. of flesh and 200 of glue were fed, so much nitrogen was excreted as to require a decomposition of 245 grm. of the flesh of the body, by the addition of 100 grm. of glue this was covered up to 77 grm. This agrees with the former experiments, and confirms our main proposition that all the nitrogen, or the greatest part of it, contained in the food is evacuated in the form of urea. With 200 grm. of flesh and 200 of glue 245 grm. of body flesh were required, with 200 grm. flesh and 300 glue only 77 grm.; 100 grm. glue are therefore equal to 168 grm. of flesh.

Three days' feeding with 500 grm. flesh and 200 of glue were followed by a gain of 316 grm., of which 134 were flesh and 182 water. When we compute the amount of heat formed, we find it necessary to reckon some fat as having been given off. The daily consumption would then be 455 grm. flesh, 20 glue, and 108 fat.

With 2,000 grm. flesh and 200 glue, fed daily for three days, the gain was 562 grm. Computing the nitrogen, there were 652 grm. flesh deposited, and consequently 90 grm. of water or fat given off. We here see that a large increase of flesh food caused a great increase in the decomposition; but we have seen previously that when fed on 2,000 grm. flesh alone he decomposed the whole, with 2,000 grm. flesh and 250 fat he deposited only 118 grm. Now, with the same quantity of flesh and 200 glue he deposited daily 217 grm. That this was not accomplished by an attraction of the glue directly for the oxygen is shown by the abundance of the decomposition products, and the amount of heat developed is considerably more than what was taken as the minimum in the fasting condition.

Three days' feeding with 200 grm. glue alone daily, gave a loss of 624 grm.—249 flesh, 322.5 fat, and 52.5 water; a loss of only 83 grm. flesh daily, an effect not produced by 340 grm. of fat.

Three days' feeding with 200 grm. glue and 200 fat gave a loss of only 94 grm., while 158 grm. of flesh were excreted in the nitrogen of the urea; there must, therefore, have been a deposit of 55 grm. fat, and 9 water.

Feeding for three days with 50 grm. of glue and 200 of fat gave a loss of 561 grm., with an excretion of nitrogen in excess equal to 593 grm. of flesh; this was derived from the body; but 32 fat-tissue were deposited, consisting of 27.52 fat and 4.48 water.

Three days' feeding with 100 grm. glue and 200 fat gave a loss of 849 grm.—310 grm. of flesh, and 549 grm. most probably of water, from the amount of fat in the food.

If we compare the last three experiments, we shall see that with the use of 50 grm. glue, 200 grm. flesh were given off from the body. With 100 grm. glue fed, 100 grm. flesh were given off; and with 200 grm. glue, only 50 grm. flesh were lost; thus there is a direct proportion between them; but as the flesh contains three times more water than the glue, one part of flesh operates equally to four parts of glue. If, therefore, the dog had consumed 250 grm. of glue, no further loss of flesh would have been sustained. The reason why gelatin proves an insufficient nourishment is that such large quantities of it are required to replace the albumen—at least four times as much glue as dried flesh, or as much dry glue as moist flesh. The animals, consequently, will not consume it. The reason why, when animals have been previously fed with glue, they have died, is twofold—first, they could not eat enough of it to cover their nitrogenous loss; and secondly, because, after the consumption of all their fat, they had no longer the means of producing animal heat.

The glue used in these experiments may be very much better than ordinary glue. This French glue, apparently, contains more chondrin, and it may perhaps contain some albumen; this seems to be the case, from its containing less nitrogen and more sulphur than common glue.

The results of these experiments may be thus briefly stated:—

In the fasting condition an animal continually loses flesh and fat, as urea, carbonic acid, and water; and this loss is in proportion to his bulk.

In feeding with flesh alone, an animal requires from $\frac{1}{20}$ to $\frac{1}{25}$ of his weight daily to maintain his condition; and as soon as he begins to deposit flesh he will consequently require his food to be proportionally increased; and this may continue until the animal has reached his maximum, and then he ceases for awhile to eat; the increase in the food causing a retention of his fat.

In feeding with flesh and fat, and with fat alone, we learn that fat is not sufficient to prevent nitrogenous decomposition; nor yet to prevent its increase when the food is increased. Moreover, the fat itself causes an increase in the nitrogenous decomposition; but it lessens the relative amount, *i. e.* less nitrogenous matter is decomposed if fat be used, than would be if it were not: thus $\frac{1}{3}$ to $\frac{1}{4}$ of the nitrogenous food will, if combined with fat, be sufficient to keep an animal in condition, to what would be sufficient without fat, and the administration of fat in the food not only saves the fat in the body, but causes more to be deposited. Sugar has a similar effect to fat, only more powerful; it cannot prevent the nitrogenous decomposition, nor its increase under increased feeding, nor the influence of the increased bulk of the organs. It acts only relatively, and by its use induces an earlier deposition of the flesh and fat contained in the food than would occur without it. As carnivora cannot be induced to take enough sugar to supply all their wants in internal motion and heat from nitrogenous decomposition, the sugar can never be deposited as fat; and, indeed, in any case this does not seem probable.

The effects of starch are similar to those of sugar, and in carnivora bread does not afford a full force-sustaining nourishment.

A more important character must be assigned to gelatin than has been previously attributed to it. It possesses the power of lessening the consumption of albumen—four parts of glue being equal to one of albumen. It cannot, however, be taken in quantity sufficient to cover the whole of the albuminous consumption. From these facts Liebig's division of food into plastic and respiratory are considerably strengthened. As, however, all depends on the truth of the proposition that all the nitrogen is excreted as urea, and that this is derived from tissue change only, in experimenting for this purpose this is the first point to be ascertained; this can easily be done by varying the weight of food and observing the variations in the amount of urea.

With regard to herbivora there are doubtless many variations, among others the formation of fat from carbo-hydrates.

The only important thing, however, in all these inquiries is to ascertain the processes which occur in man. The first step to be ascertained is in what condition he excretes nitrogen in urea only, and in what other form, if any. Experiment alone can determine this. One thing, however, is certain, that the so-called "normal diets," and the "equalizations of food," which have been hitherto founded on general rules, are of no use at all, as affording any guide in any particular individual case. Each one is a law only to himself, and varying circumstances will cause such variations in every individual that a special calculation will be required to meet them. The stronger the man the more food will he require to maintain his strength than a weaker man, the exercise of both being equal.

The bulk of the organ, the amount of the plasma, that of the disposable oxygen, and the energy of the nerves constitute the four great factors in the acts of decomposition; these are always equal to one another, or are striving for an equality, in which the force needed for motion and the animal heat are liberated.

In an appendix are some remarks on the urine and feces, and some analytical tables.

In presenting this abstract of Bischoff and Voit's treatise, we have departed from our original intention, and we trust not unacceptably to the reader. The importance of the subject, the small probability of such a treatise being translated, and the fact that it is, in its original, out of the reading of a large number of the profession, are our reasons for this change. The doctrines herein taught, although we cannot agree with all his conclusions, yet, taken as a whole, give a much clearer insight into many of the conditions of diseases from malnutrition in their earlier stages than we previously had. The rapidity with which the blood and tissues exchange their solids for water, coupled with the fact mentioned by Ricord on one side, that in cases of enlarged lymphatic glands the blood is always watery; and on the other side with the notorious connection between lymphatic glandular enlargements and phthisis or scrofula, advance our knowledge one step, if only a short one, in the comprehension of this subject. Thus, we see a child in apparently good condition, *i. e.* plump, and yet here are these incipient scrofulous developments—the condition of the child becomes so much more intelligible, and the indications of treatment so much the better grounded. Nor can it be too strongly impressed on the mind of the parents of every such child that dietetics must be the chief means to be depended upon to protect the child from further developments. While with the profession the more minute the study into the earliest symptoms, or the predisposing causes of this scourge, the greater will be the possibility of averting its destructive progress. The profession has been too long engaged about the means of its *cure*, to pay much attention to those of its *prevention*, or of its *arrest*. One specific is vaunted after another, to receive the same summary dismissal; and thus the investigation into principles has been neglected, from which alone we can with reasonable hope expect success.

The view promulgated by Liebig, that the alkaline carbonates contained in the blood are the carriers of carbonic acid out of the system to the lungs, where it becomes disengaged, and the opinion that the globules are the main carriers of oxygen into the system, have received strong confirmation from the researches of M. Fernet; he found also that the absorption of oxygen by the serum was in inverse proportion to the amount of salines present. Consequently, where the salines are in excess, and the globules deficient, a very large deficiency of oxygen in the system would so reduce one of the factors of tissue change—to say nothing of a second, the nerve force—that the whole internal workings would be deranged, the assimilating organs would have no material with which to do their work, the excretory organs would be overtaxed, the nitrogenous decomposition would sink very low, and consequently the need of supply would cease, effete matter would be long retained in the tissues, the result of this cessation of tissue change, and a faulty structure would result, which will be only ready to decay: the frequent complication of anæmia and chlorosis with phthisis, and the great preventive of, and remedy for, this disease, *fresh air*, and increased respiration of oxygen, combined with a nitrogenous or blood-corpuscle making diet, witness to the correctness of these views, for even when the fat "cod-liver oil" is beneficial, the appetite is increased and the powers of assimilation strengthened. But we have need of a much enlarged conception of the minutiæ to make our views practically applicable to the larger number of cases, and an acquaintance with nutrition in health must precede that of nutrition in disease.

Another point against which we cannot too strongly urge, is the "doctrine of averages," and its twin sister, the "numerical method." In nature there never was, nor is, nor ever will be such an anomaly as an average. Everything is the absolute and certain result of fixed and definite causes. Alter these in any way, even to the least degree, and the results vary *accordingly*, and in a *fixed and certain proportion*. She knows no "medium;" she knows nothing but a unit; and this unit is a combination of facts, varying in each, and therefore originating results varying correspondingly—experimentation therefore, and the accumulation of facts, can alone furnish us with the key to her enigmas—and each fact is valuable, just in proportion as *all* its conditions are *accurately* ascertained, and in that proportion only; and in collecting these facts we should be careful not to allow "preconceived ideas" to become "fixed ideas." The former are necessary, indispensable; we can do nothing without them; we should only know how to abandon them when they are no longer right. The preconceived idea is always interrogative; it addresses the question to nature, and calmly awaits the answer; ceasing to question when this is received, and adopting the fact, whether opposed to, or in accordance with itself, with the same readiness (Bernard).

That the carbon and hydrogen present exert a powerful influence on the results of nitrogenous decomposition cannot for a moment be doubted; the power which we possess of varying the amount of urea and uric acid, and of producing hippuric acid, evidence this; and, also, that in the decomposition all the elements are reduced to the nascent form.

In conclusion we may remark, that in framing a dietary, especially in convalescence and in health, no difficulty will be found when these principles are borne in mind, and the albuminous foods most readily convertible into albuminose, combined with such proportions of fat, sugar, and starch as the condition of the assimilating organs can appropriate without subsequent ill effects; and in such quantities of each that the excess, if any, be slightly on the nitrogenous side of the scale, will be generally the most advantageous, only remembering that the fat cannot be too free from rancidity, nor the sugar too pure, and especially should this be remembered in the feeding of children; while in all the use of gelatinous food should be but sparing.

And while the use of fresh lean meat cannot be too strongly inculcated, an abundance of pure fresh air is of no less importance; for out of door exercise imparts an energy to the system often unknown before, and unattainable by any other means; the more rapid the tissue-change, provided its replacement correspond, the less effete matter will be in the system, the more vigorous will be the frame, and the better able to withstand the inroads of disease.

NOTE.—In my last article, on page 356, in the enumeration of the elements, read S for I, and in line fifteen from bottom omit "may undergo decomposition in the system, or." It will thus read: "it may give rise to decompositions," &c. &c. Elementary bodies cannot be decomposed.